

## Background of the Invention

[0002] In traditional welding operations for the production of small batches of welded structures the welding is normally performed at least mainly manually. This is because the main parts of most structures are neither technically nor economically suitable for welding using present automatic welding apparatus. With the welding of small batches, known welding apparatus is suitable only for welding very accessible, long and straight welds. However often the majority of welds in a welded structure are for joining relatively short intersecting structures whose accessibility is limited by the surrounding constructions. This is a particular problem in shipbuilding, where the number and relatively large size of different parts cause problems. The manual welding of such structures is both expensive and time-consuming.

[0003] Welding systems have been developed where the structure to be welded is followed according to its form or shape using different kinds of control arrangements. One such known welding system is disclosed in DE-A-2240949, wherein a steering wheel is used to control the path taken by welding apparatus. In US-A-5307979 a welding system is disclosed in which a rail-based control arrangement is provided for welding three-dimensional structures. In DE-A-2035498 a system for welding tires is disclosed.

[0004] Automatic welding systems are disclosed in US-A-4737614, in which a control system is based on variations in the intensity of light, and in US-A-5572102 in which a welding robot system is employed based on fluorescent light.

[0005] Welding benches have also been developed which can be adjusted according to the structure to be welded; see for

example EP-A-0092533. It is also known to automatically weld pipes as disclosed in SE publication 455581.

[0006] There are considerable disadvantages with known welding techniques and in particular in most cases it is not possible to apply them to the ship building industry. Generally for a ship, welded structures are required which have relatively large dimensions, typically over 10 m wide and often even nearly 20 m long. When transverse and longitudinal constructions are attached to these structures the welding usually has to be performed by hand which takes a great deal of time. The use of thinned materials and the use of, e.g., reduced "throat" thicknesses, has additionally caused the nature of welding to change. Welding has also become ergonomically difficult because of increased welding speeds. Furthermore the use of a skilled welder for relatively simple but tedious welding work is impractical since it wastes the ability of the skilled welder. It is more sensible to use manpower for meaningful work which a machine cannot do.

[0007] An aim of the present invention is to eliminate these disadvantages associated with known welding techniques and to achieve a totally novel solution for welding together a plurality of typically differently shaped pieces, the welding operation being easy to control and to adapt to different circumstances. It is also intended to be able to adapt the invention to different technical fields where there are requirements for welding pieces having a great multiformity and diversity. Examples of fields where the invention has applicability are paper machines, general building applications, bridge and train building, and heavy vehicle, e.g. truck, manufacture.

#### Summary of the Invention

[0008] According to a first aspect of the present invention there is provided a method of forming a welded structure comprising arranging on constituent pieces of the structure to be welded on a support surface in a desired configuration, recording at least one image of the

arrangement of the constituent pieces on the support surface, determining from the image(s) the positions of a plurality of weld points, welding with welding apparatus the constituent pieces together at said weld points to form the welded structure, and controlling the welding of the constituent pieces with said welding apparatus on the basis of the determined positions of the weld points.

[0009] According to a second aspect of the present invention there is provided a method of forming a large welded structure, for example a part or parts of a ship, a paper machine, a building, a train or a truck, comprising arranging constituent pieces of the structure to be welded on a support surface in a desired configuration, recording at least one image of the arrangement of the constituent pieces on the support surface, determining from the image(s) the positions of a plurality of weld points, welding with welding apparatus the constituent pieces together at said weld points to form the welded structure, and controlling the welding of the constituent pieces with said welding apparatus on the basis of the determined positions of the weld points.

[00010] According to a third aspect of the present invention there is provided a welding arrangement for forming a welded structure from a plurality of constituent pieces, comprising a support surface for supporting the constituent pieces in the configuration of a structure to be welded, camera means for providing an image of the structure to be welded, evaluating means for determining the positions of weld points of the structure to be welded based on the image provided by the camera means, welding apparatus for welding together the constituent pieces of the structure at the positions of the weld points determined by the evaluating means.

[00011] The invention is based on the idea that the pieces to be welded are placed on a support surface in their desired final positions. The support surface can be an immovable surface, e.g. held against movement, or a movable base or floor surface whose position is known. Suitably a support structure or supporting construction is supported on the

[00012] The invention enables the constituent pieces of one or more structures to be welded together. The dimensions of the structure and of its constituent pieces are photographically recorded to enable the different weld points to be determined. These weld points can be determined by scanning or reading the photographically recorded information and passing the scanned or read information to control means. The control means is used to control the welding together of the pieces of the structure to be welded based on the determined positions of the weld points. The scanned or read photographic information may be stored or recorded in memory means, e.g. of a scanning/reading apparatus, of the welding apparatus and/or of the camera or photography means.

[00014] Conveniently the camera or photography means is used to acquire views of the structure to be welded, these photographed views being used to enable reader/scanner apparatus, either automatically or with assistance of a user, to identify and define the positions of the weld points. Once the weld points are so defined they are used for the manual, semi-automatic or automatic welding of the constituent pieces of the structure to be welded. The actual

[00018] Conveniently the welding system, based on the welding map, automatically recognizes so-called standard welds, characteristics of which may, for example, be pre-learned by the computer, so that the system can automatically instruct a welding robot or the like to commence welding.

[00020] By the invention noticeable benefits are obtained. In particular a low cost welding system can be provided in which welding apparatus (robots) can be taught to weld separate pieces together. Additionally the system is able to cater for the welding together of pieces having different shapes and sizes. Typically the welding method can be used to program the welding of small batch productions, the welding of serial production products and the welding of prototypes or the like.

[00021] Embodiments of the invention will now be described, by way of example only, with particular reference to the accompanying drawings, in which:

[00024] FIG. 3 is a representation of the structure to be welded formed by evaluation of the photograph shown in FIG. 2, and

### Detailed Description

[00026] FIG. 1 shows a welding station or arrangement in which a plurality of constituent pieces of a structure 1 to be welded are supported on a support surface 2. The pieces may be moved onto the support surface manually, with a crane or with automated material management means. A camera 3 and a welding machine 4 are attached to a transverse supporting

[00027] The term "camera" is intended to cover any imaging means able to provide an image of the structure to be welded and may comprise conventional photography apparatus, e.g. a video camera or still camera, imaging means recording infrared or ultra violet radiation, laser means or the like. More than one such camera 3 may be provided.

[00029] FIG. 3 illustrates a visual representation of the structure 1 to be welded produced automatically and/or with the assistance of input from a user, from the photograph 9 shown in FIG. 2. The visual representation identifies, either automatically or with the help of user input, different pieces 11a, 11b and 11c of the structure and different fastening places (i.e. weld points) 11d, 11e and 11f and also provides instructions for welding the weld pieces together. The user is given the opportunity whether to approve or to reject a starting point 11d, 11e or 11f for the welding procedure and whether to approve or to reject welding methods proposed by the system. In the event that the user rejects the starting point proposed by the system, the system may propose another starting point. The welding system can thus be regarded as being semi-automatic.

[00033] Other embodiments of the invention are feasible within the scope of the ensuing claims.